Water and Wastewater Management for Gas Extraction from Marcellus Shale

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Water Supply Issues

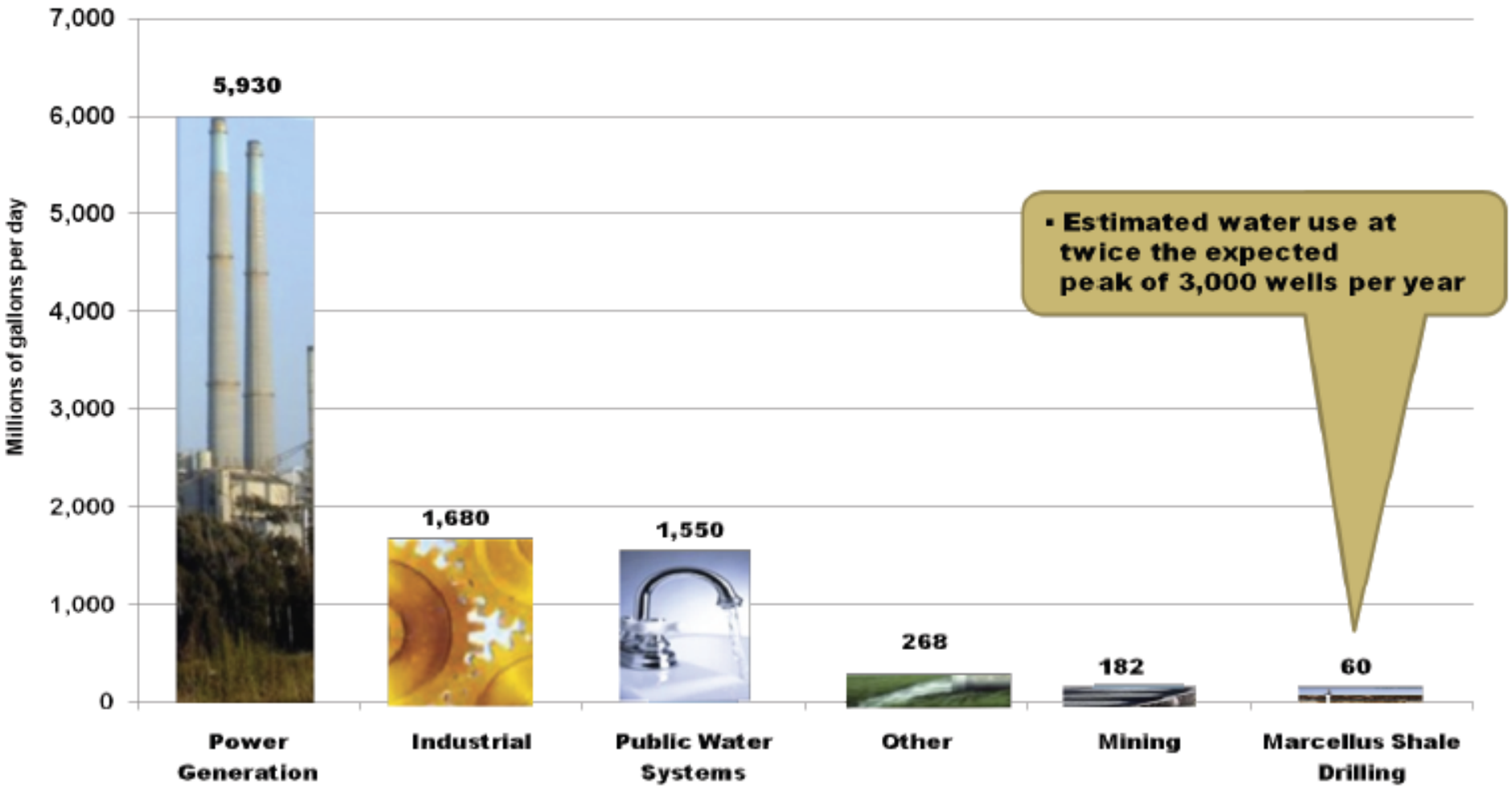
- Need 2 to 6 Million gallons of water per well for hydrofracturing
- Surface Water Withdrawals
  - Concerns about depletion of water resources, especially in drought years
  - Impacts to aquatic life
  - Ability to get withdrawals approved
  - Don't really need high quality water, but consistent quality is important
- Transportation of water
  - 1 MG = 200 trucks
  - Cost can be significant ($0.1/bbl to $2/bbl)
- Water storage on site

Water Supply Issues in PA

- Need 2 to 6 Million gallons of water per well for a multi-stage hydrofracturing

Water-use category	Water withdrawal (MGD)	Percentage (%)
Public supply	1420	15
Domestic	152	1.6
Irrigation	24.3	0.3
Livestock	61.8	0.6
Aquaculture	524	5.5
Industrial	770	8.1
Mining	95.7	1
Thermoelectric power plants	6430	67.7
Marcellus Shale exploitation in 2013	18.7	0.2

Water Use in PA



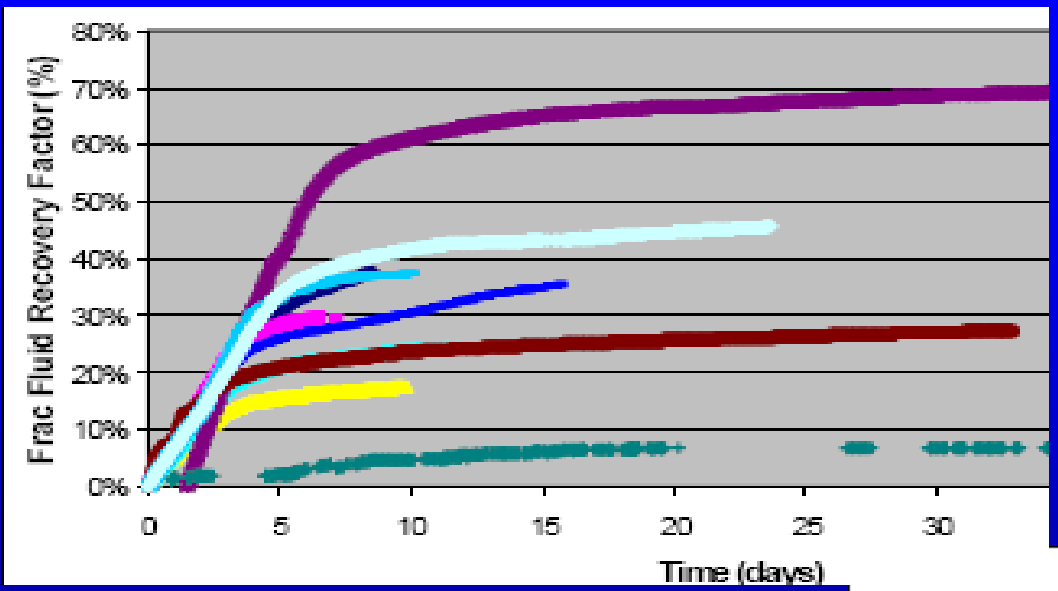
Source: USGS, Pennsylvania Water Consumption

Marcellus Shale Play is not a significant water user in PA

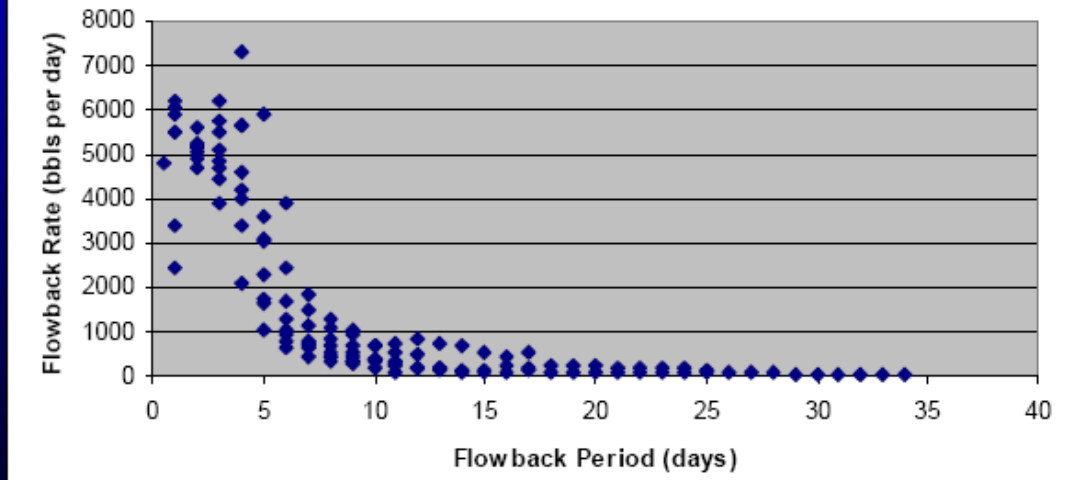
Wastewater Issues

	Flowback water	Produced water
Flowrate	High	Low (10-50 bbl/day)
Duration	1 – 2 weeks	Life of the well
TDS	< 150,000 mg/L	> 200,000 mg/L
Composition	Chemical additives Naturally occuring constituents	Same as flowback

Flowback Quantity vs. Time

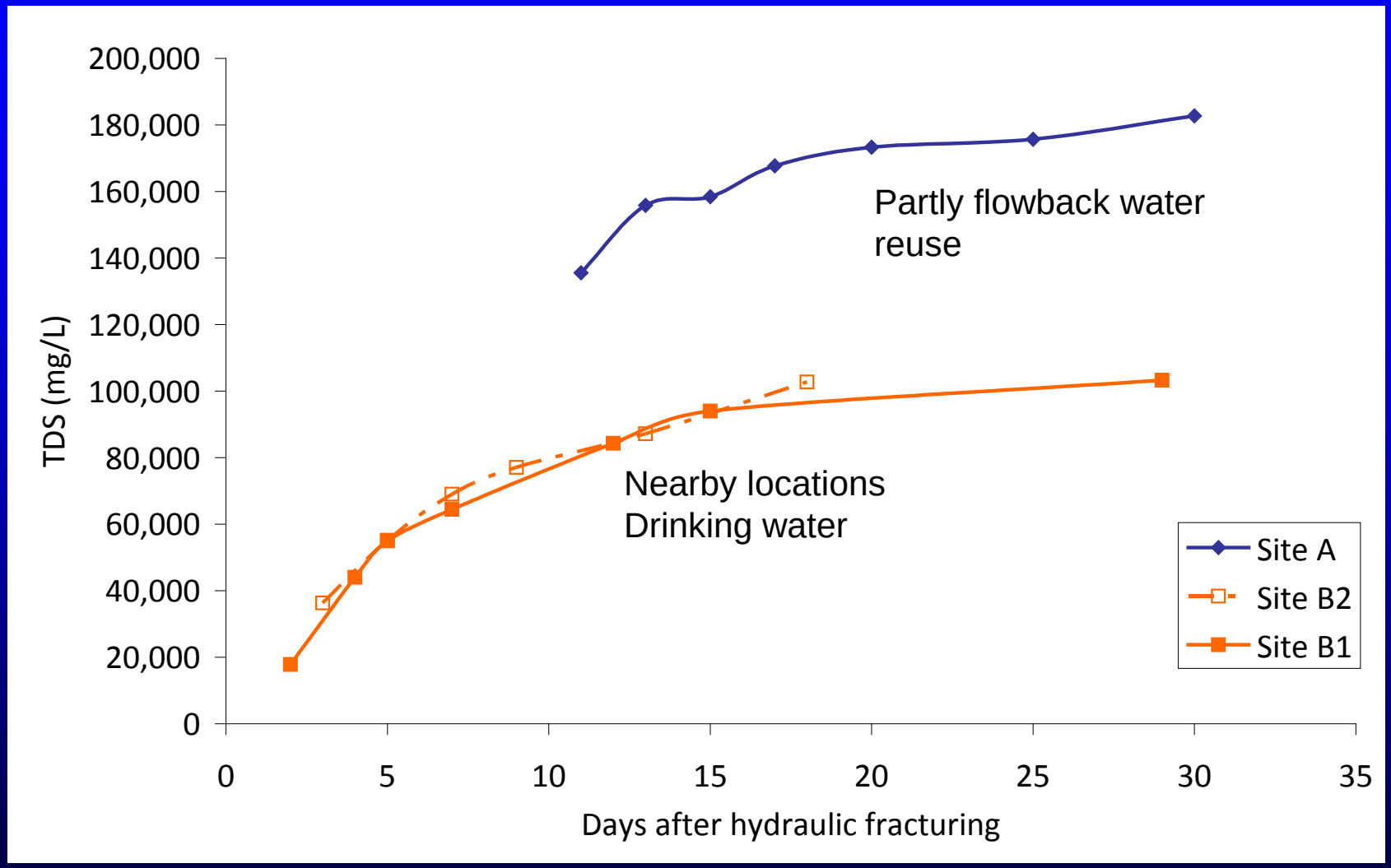


Horizontal Shale Flowback Rates



Hayes, 2009

Flowback Water Quality evolves with Time



Regular TDS increase

Flowback Water Quality

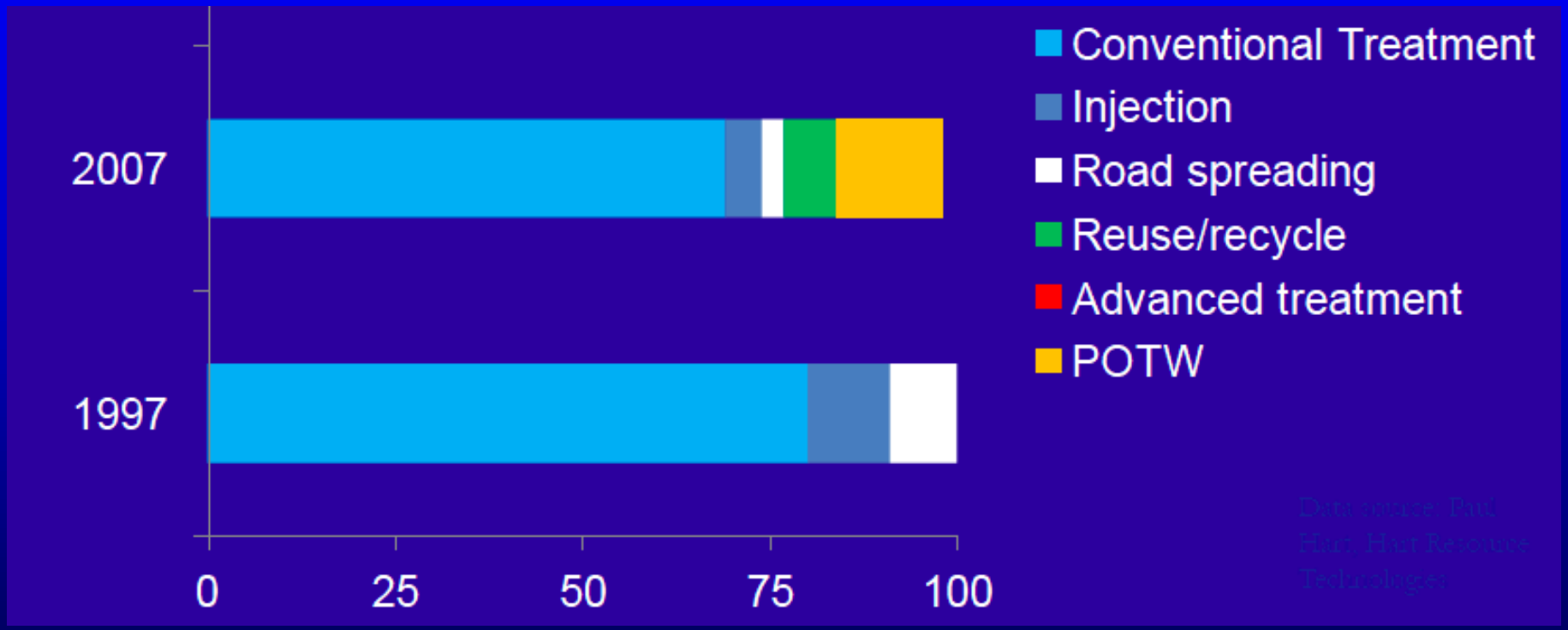
Constituent	Low	Medium	High	No. of samples
Ba (mg/L)	0.24	2,224	13,800	159
Sr (mg/L)	0.59	1,695	8,460	151
Ca (mg/L)	37.8	7,220	41,000	159
Mg (mg/L)	17,3	632	2,550	157
TDS (mg/L)	680	106,390	345,000	129
COD (mg/L)	195	15,358	36,600	89
Gross beta (pCi/L)	75.2	43,415	597,600	NE PA
Ra^{226} (pCi/L)	2.75	623	9,280	46
U^{238} (pCi/L)	0	42	497	14

Barbot et al., ES&T, 47, 2562-2569, 2013

Wastewater Management Options

- Waste disposal
  - Injection/disposal wells
  - Discharge to POTWs/CWTs
- Treatment for:
  - Reuse
  - Surface discharge

Gas Drilling Wastewater Management



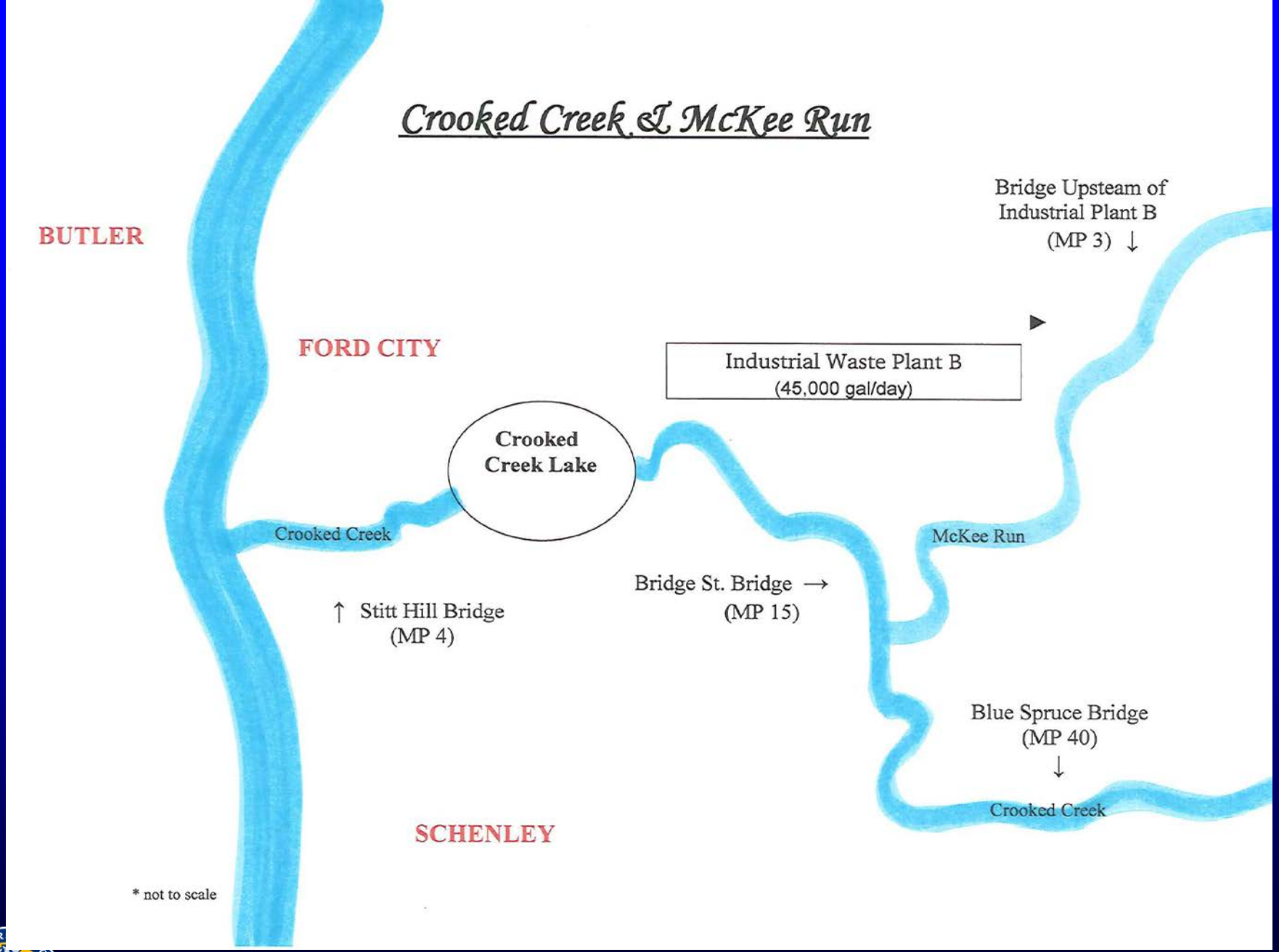
(Hart, P., 2011)

Disposal Wells

- Require demonstration that injected fluids remain confined and isolated from fresh water aquifers
- Limited capacities (1200 to 3000 bpd)
- Substantial capital investment with uncertain life span ($1M to $2M)
- Probably will only play a limited role

Disposal to Treatment Plants (POTWs or CWTs)

- Used in the past
- POTWs use biological processes that cannot handle high salinity
- Existing CWTs are no longer permitted to accept Marcellus Shale wastewater


Crooked Creek & McKee Run
BUTLER
FORD CITY
SCHENLEY
Bridge Upsteam of
Industrial Plant B
(MP 3) ↓
Industrial Waste Plant B
(45,000 gal/day)
Crooked
Creek Lake
Crooked Creek
McKee Run
Bridge St. Bridge →
(MP 15)
↑ Stitt Hill Bridge
(MP 4)
Blue Spruce Bridge
(MP 40)
↓
Crooked Creek
* not to scale

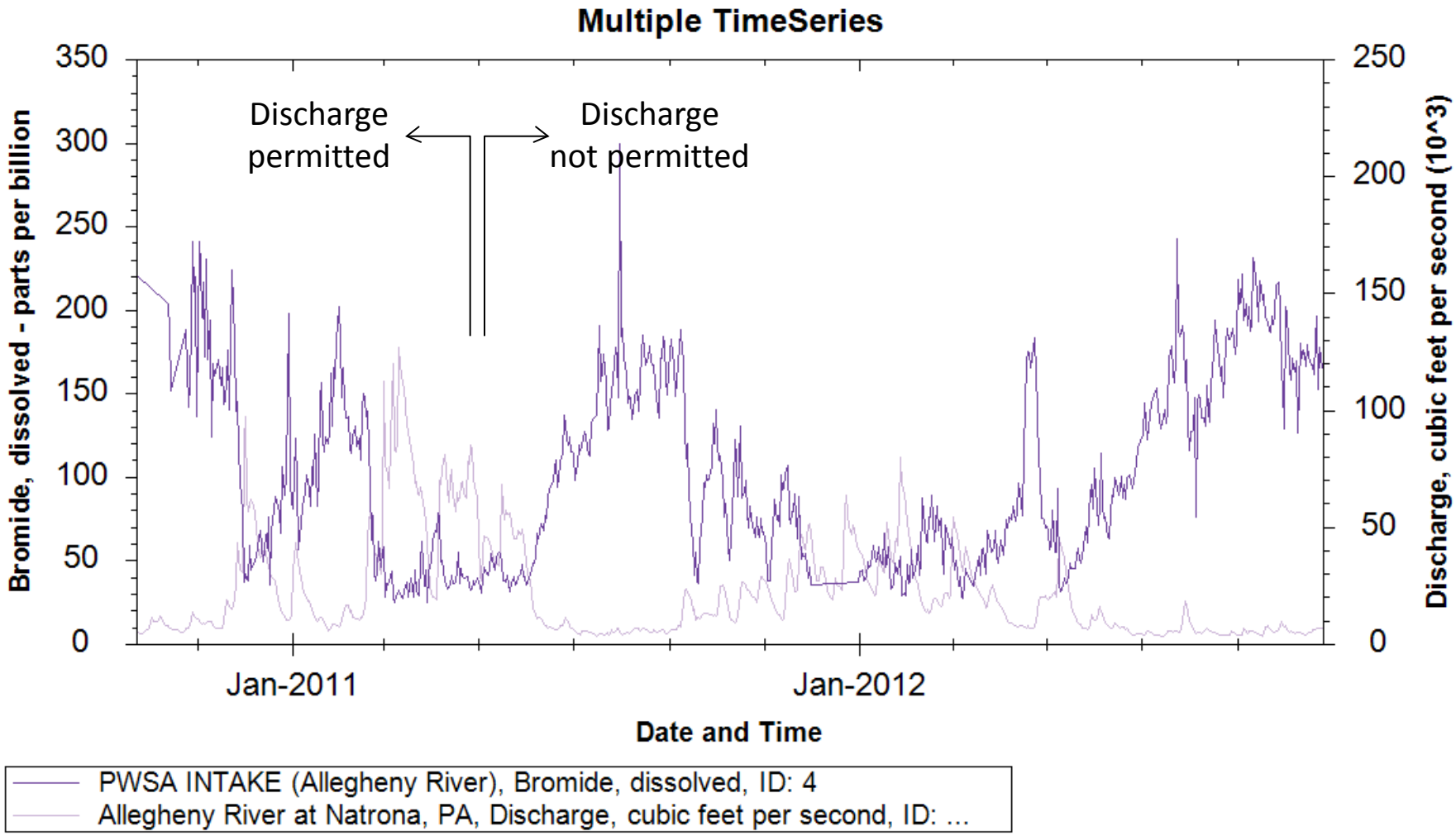
CROOKED CREEK & McKEE RUN

Bromide Concentration (ppb)

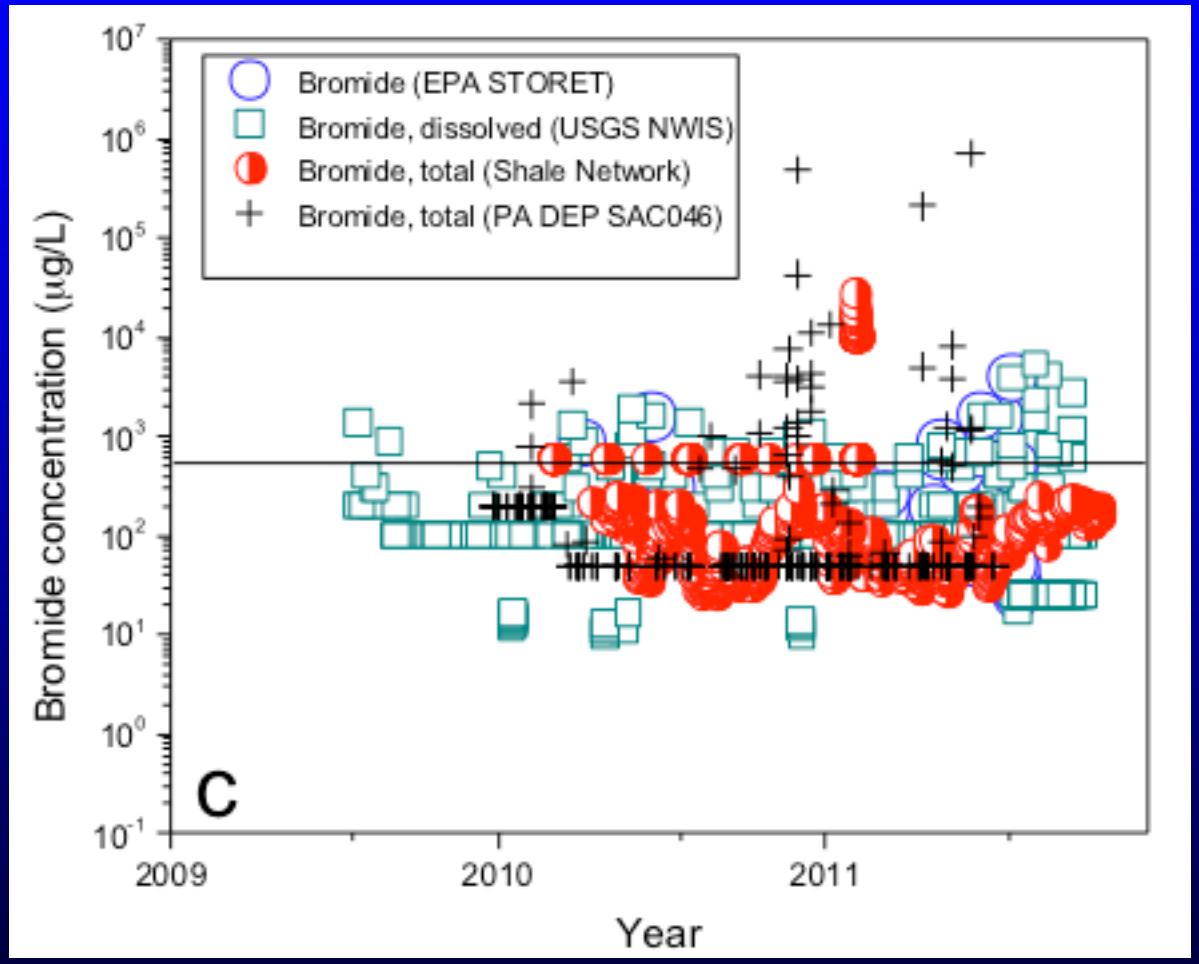
Sample Site		Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	March 2011	April 2011	May 2011	June 2011	July 2011	Aug 2011	Sept 2011	Oct 2011
McKee Run	Upstream of Plant B		29	79	61	36	27	17	32	66	93	63	26	25
	Donwstream of Plant B	20 X	10 X	9 X	10 X	1.1 X	3 X	3 X	8 X	8 X	27 X	34 X	4 X	17X
Crooked Creek	Blue Spruce Bridge	57	39	64	87	37	38	13	53	83	116	114	56	25
	Bridge St. Bridge	1130	345	639	774	42	111	44	414	640	3100	3900	214	427
	Stitt Hill Rd. Bridge		280	467	396	173	74	53	112	258	578	582	426	103

(Casson, L., 2012)

Br in Allegheny River at PWSA intake



Bromide in surface water versus time for all available data in Shale Network database for 40 PA counties with Marcellus drilling



High concentrations since 2003 were generally in areas with permitted brine discharge or for Salt Springs. Line = 3σ above mean from 1960-2003 for USGS data (early data not shown). Detection limit = 10 – 200 ug/L.

Includes data from EPA Storet, USGS NWIS, SRBC, Appl. Geo. Consulting, ALLARM, PA DEP

Vidic et al., Science, 2103

Vidic et al., Science, 2103

Very few examples of WQ problems today from the database

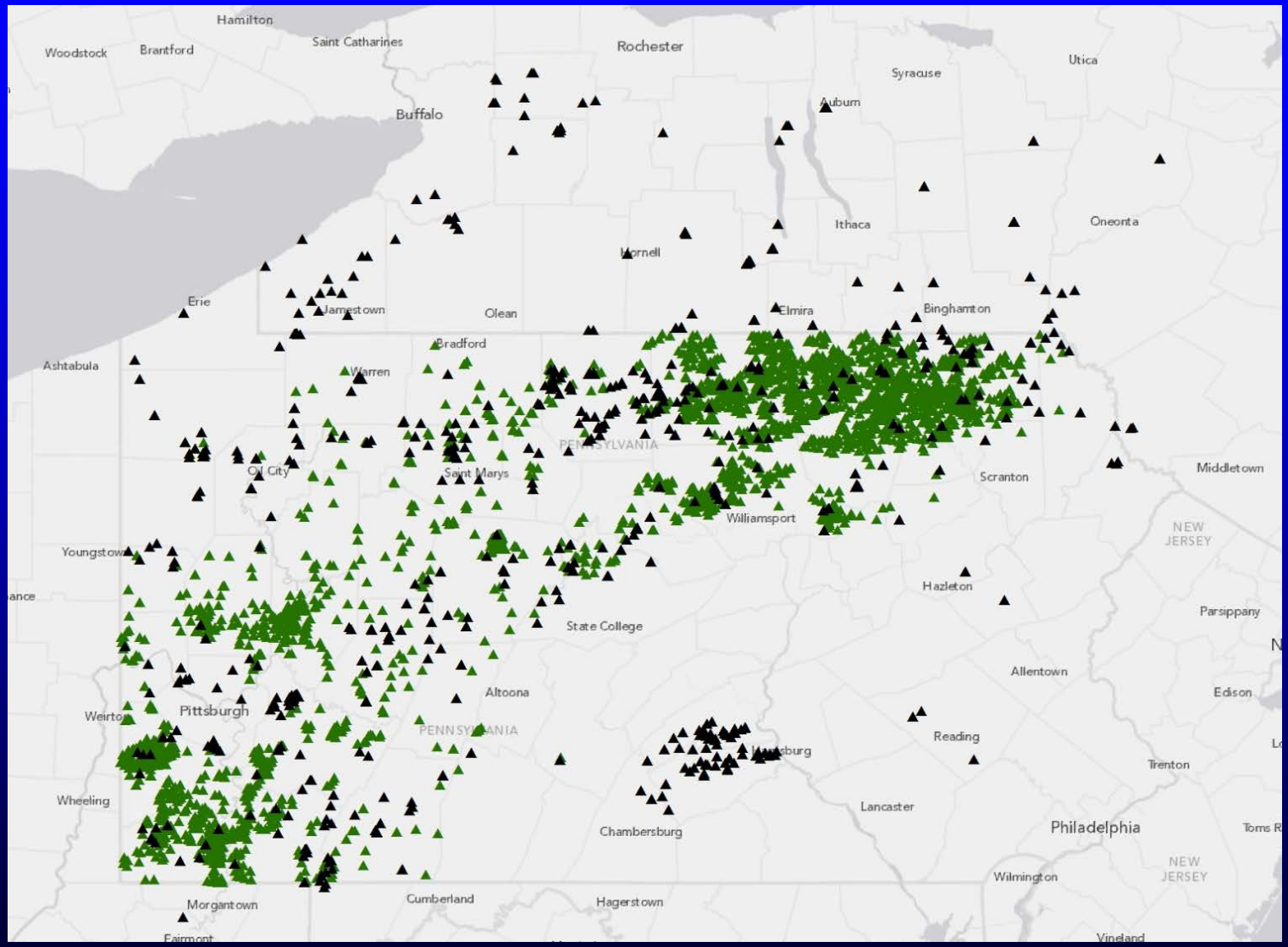
There are many problems but…

- We haven't had enough time to look for them
- Spills and other incidents are relatively small and local –
- Sensors or sample-taking is occurring in the wrong places
- Sensors or sample-taking is not aimed at the right analytes
- The important effects are cumulative and incremental and difficult to see
- Data are generally not being released (we just need to advocate for release of data from government, industry, private homeowners)
- Water quality in PA is already impacted in many places
- We do not have analytical tools for many organic contaminants
- Maybe contaminants have been released in the solid phase – cuttings, sediments – that will release contamination over time or under different conditions

There are *not* a lot of problems..

No matter how hard we look in natural waters, we will not see many WQ issues documented because contaminant output is small compared to water fluxes

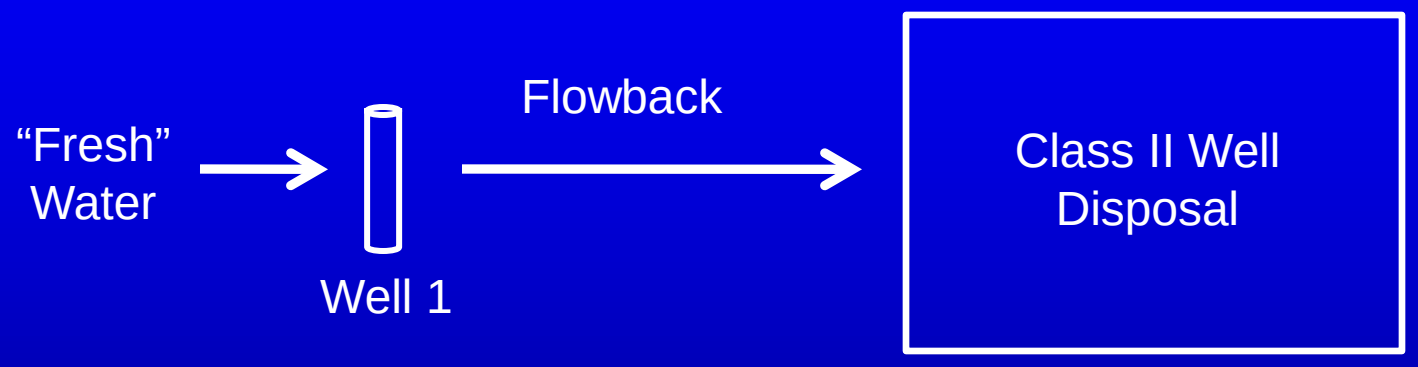
Density of sampling sites vs. density of wells



Treatment for Reuse in Fracking Operations

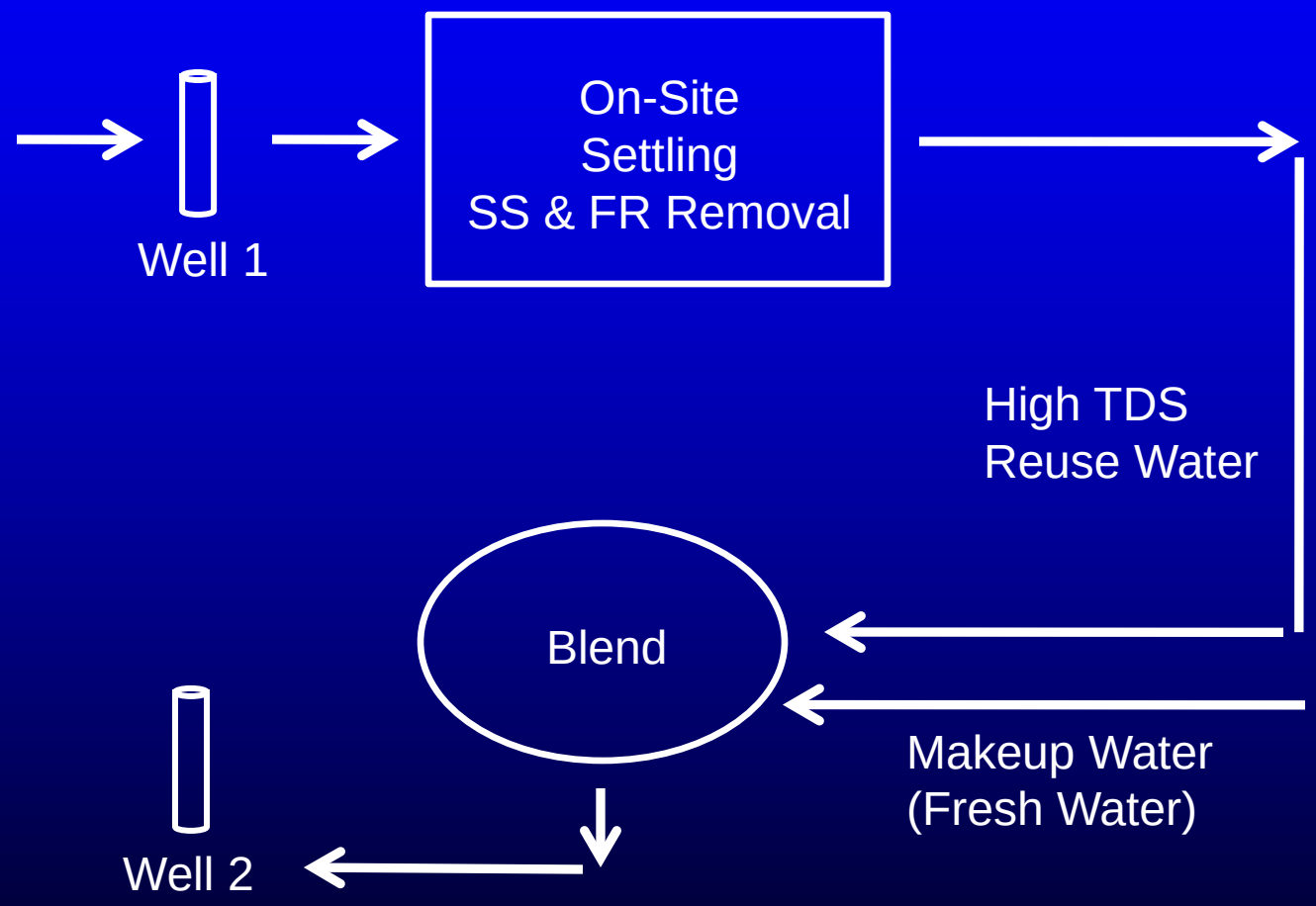
- Reduce O&G industry needs for surface water
- Reduce overall management costs
  - Volume reduction
  - Transportation costs
  - Disposal costs
- Reduce potential liability

Flow scheme 1: Conventional Water Management

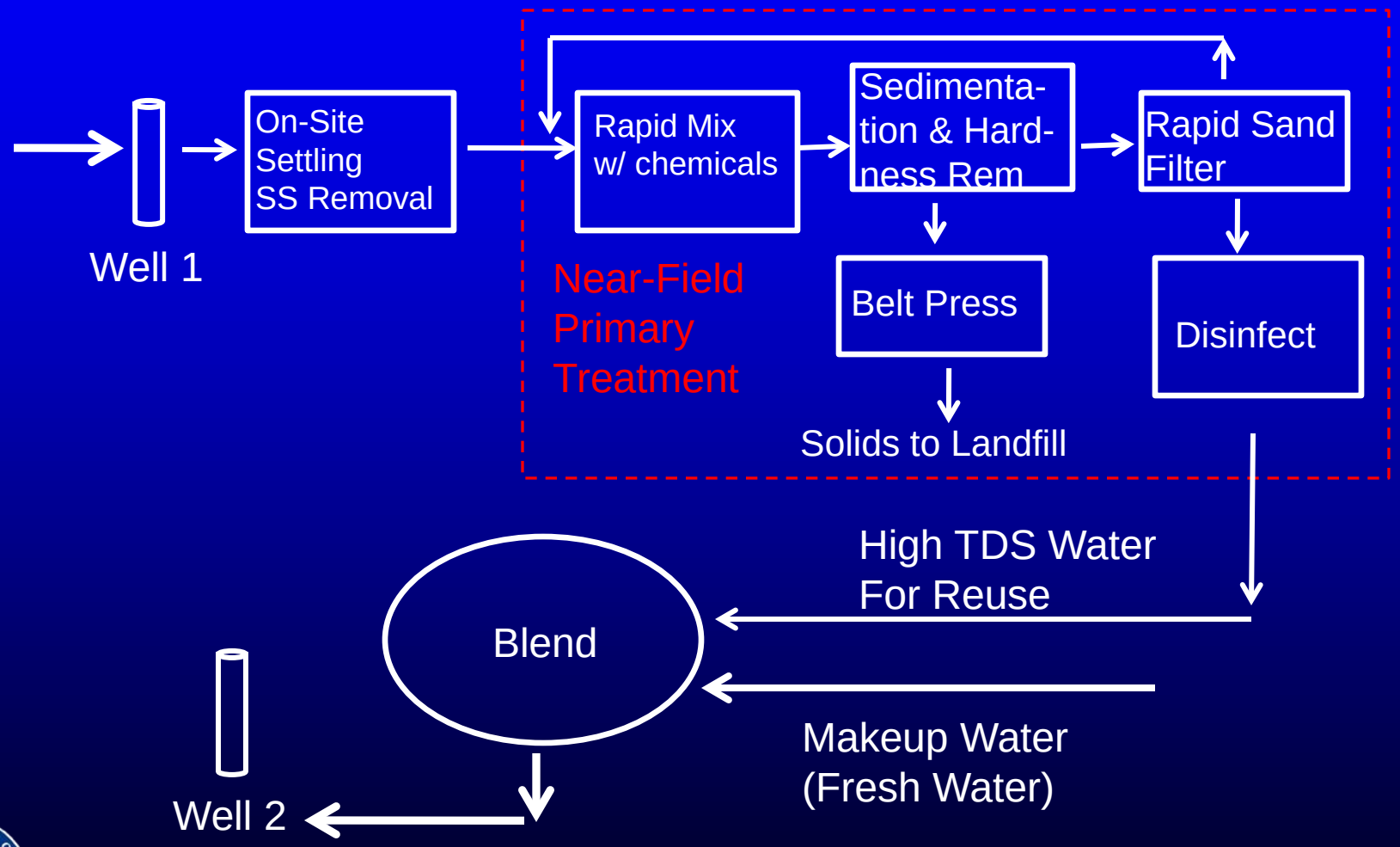


- Represents Maximum Water Demand (No Water Reuse)
- Conventional approach in Barnett and other plays
- Difficult in Marcellus (only 5 Class II wells)

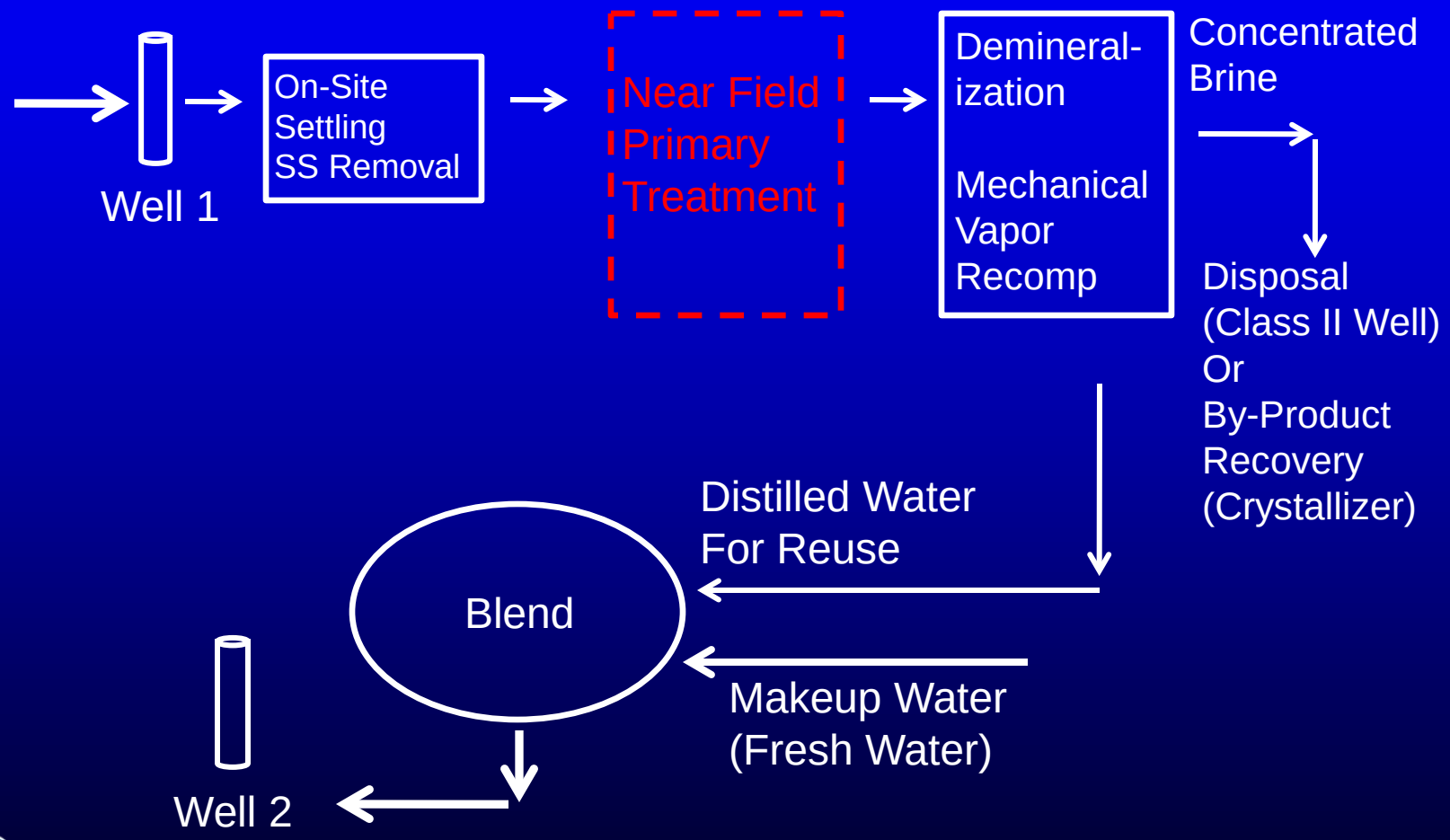
Flow scheme 2: On-Site Primary Treatment for Reuse



Flow scheme 3: Off-Site Primary Treatment for Reuse



Flow scheme 4: Off-Site Primary Treatment and Demineralization

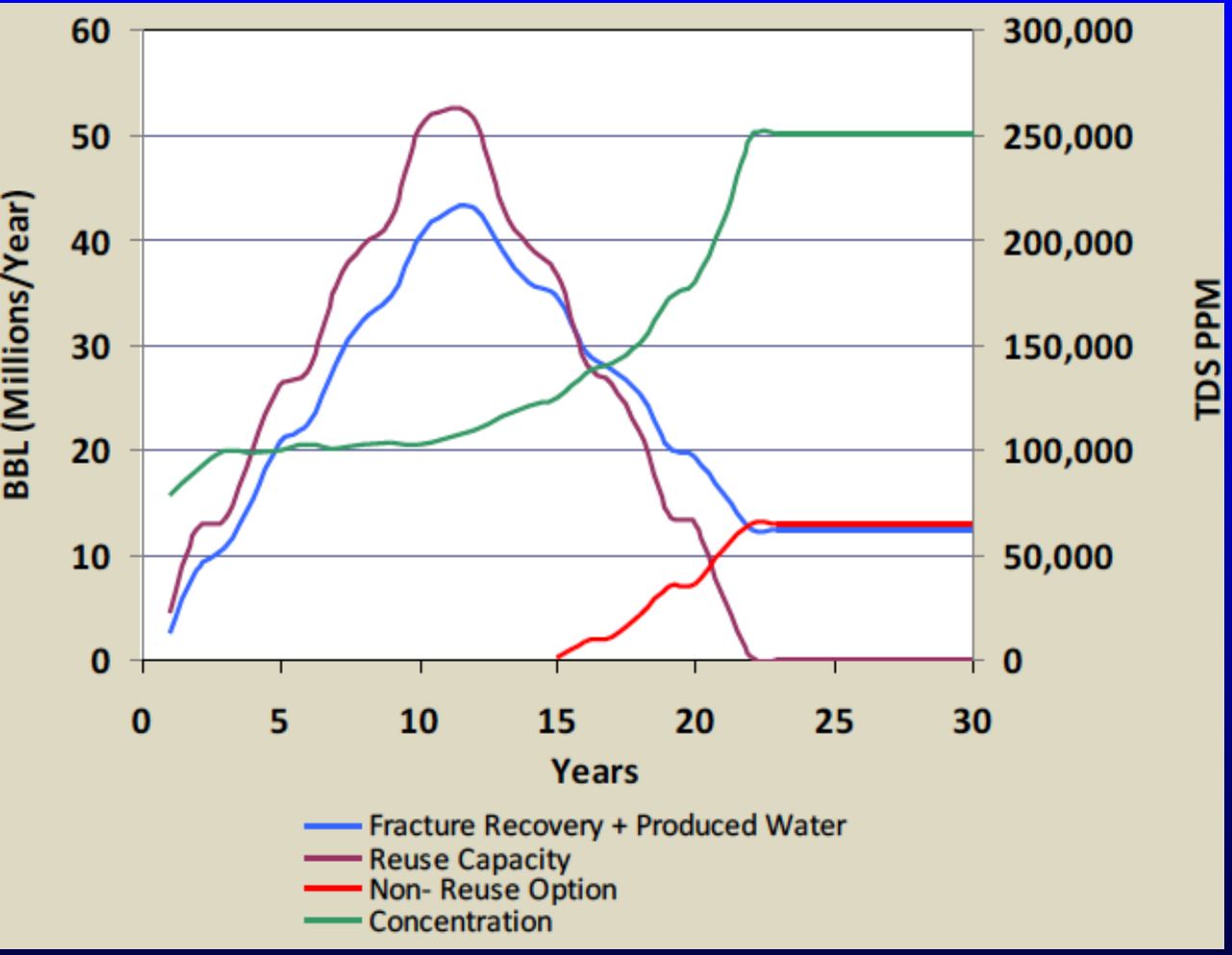


Economic Comparison of Flow Schemes

Basis: 1 million gallons of flowback (23,800 barrels)

Flow Scheme	FS 1	FS 2	FS 3	FS4
Method	Transport to Class II Well for Disposal	"In Field" Primary Treatment for Reuse	"Near Field" Precipitation for Reuse	"In-Field" Evaporation for Reuse
Treatment $	-	71	83	119
Transport $	75	1	24	24
Brine Disposal $	60	-	-	19
Sludge Disposal $	-	2	6	6
Total Cost ($x1000)	135	74	113	168
Cost per barrel	5.67	3.10	4.75	7.05
Hardness Removal	100%	0%	97%	100%
Ba removal	100%	0%	99%	100%
Salt Removal	100%	0%	0%	100%
Water reused	0	99%	97%	90%

Recycling/Reuse

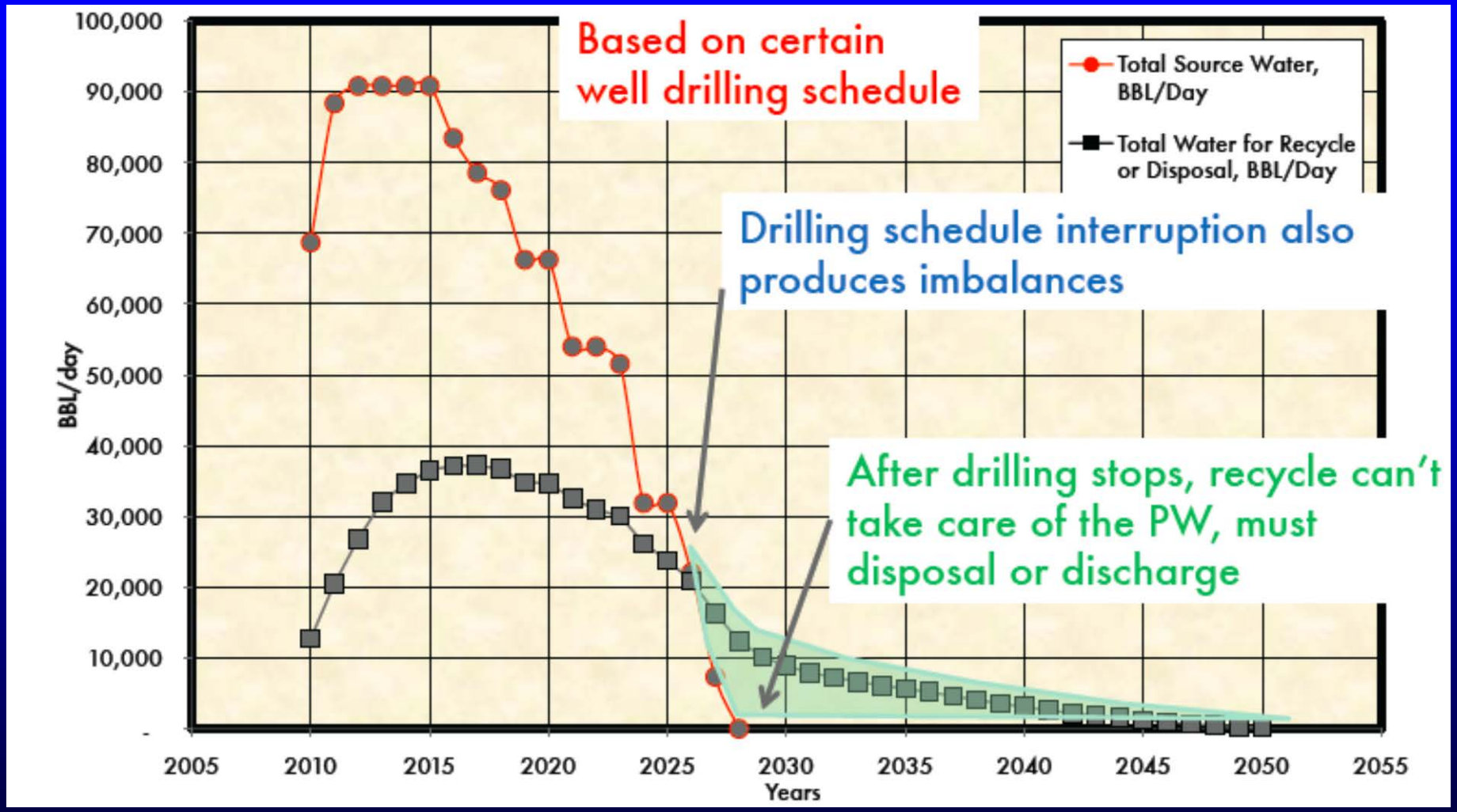


- 4800 wells on 625 mi^2
- 3 refractures/well
- 33% water reuse

- Works for 12-15 yrs

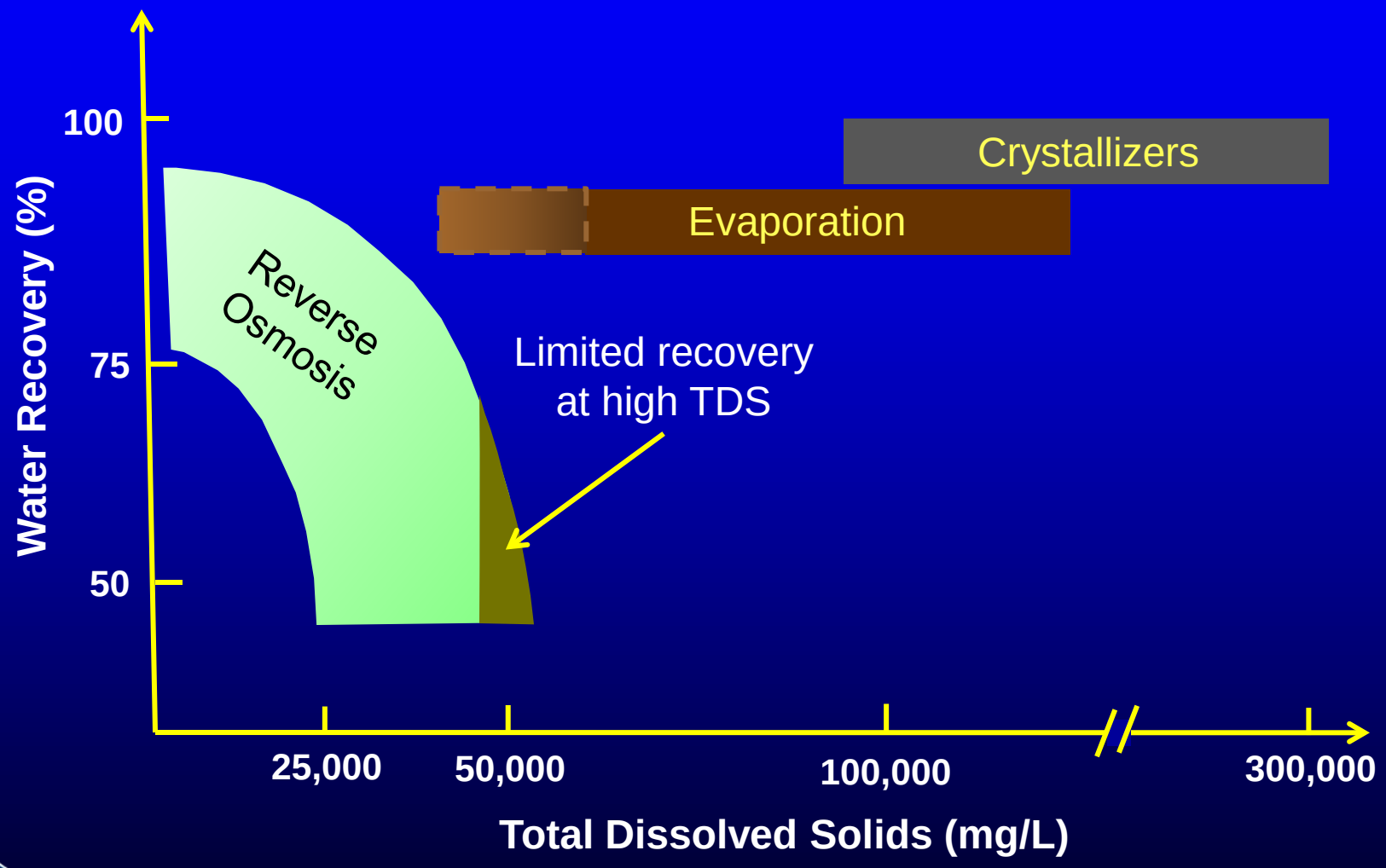
- Eventually net water production in a filed

Total Water Balance Within a Gas Field



(Kujivenhoven et al., 2011)

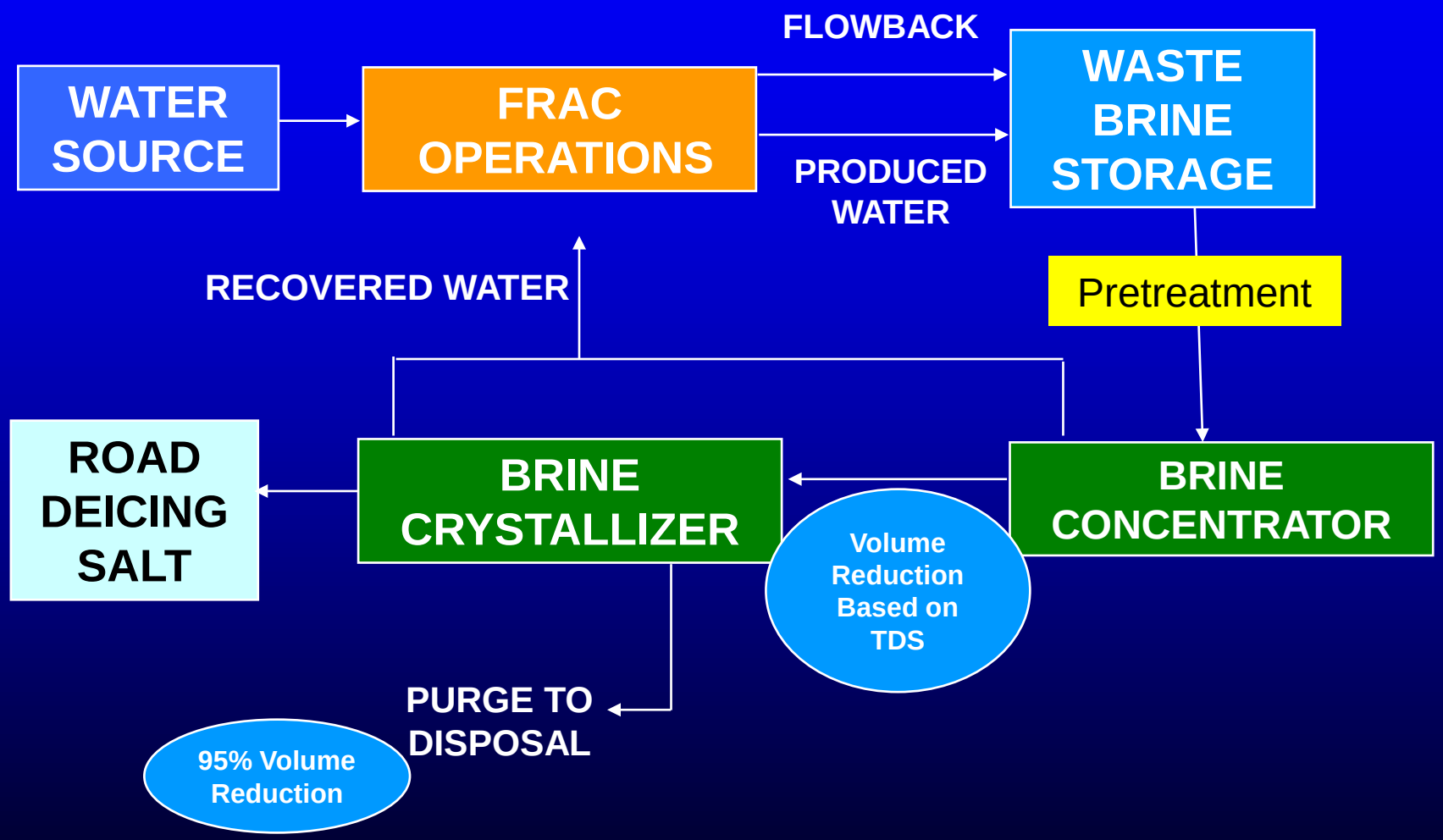
Treatment Options



Thermal Treatment

- Only alternative if there is a need to produce water suitable for disposal
- Suitable for remote locations without infrastructure or for centralized treatment plants
- Can be followed by a crystallizer for enhanced water recovery and salt production

Complete Treatment Process



Crystallization

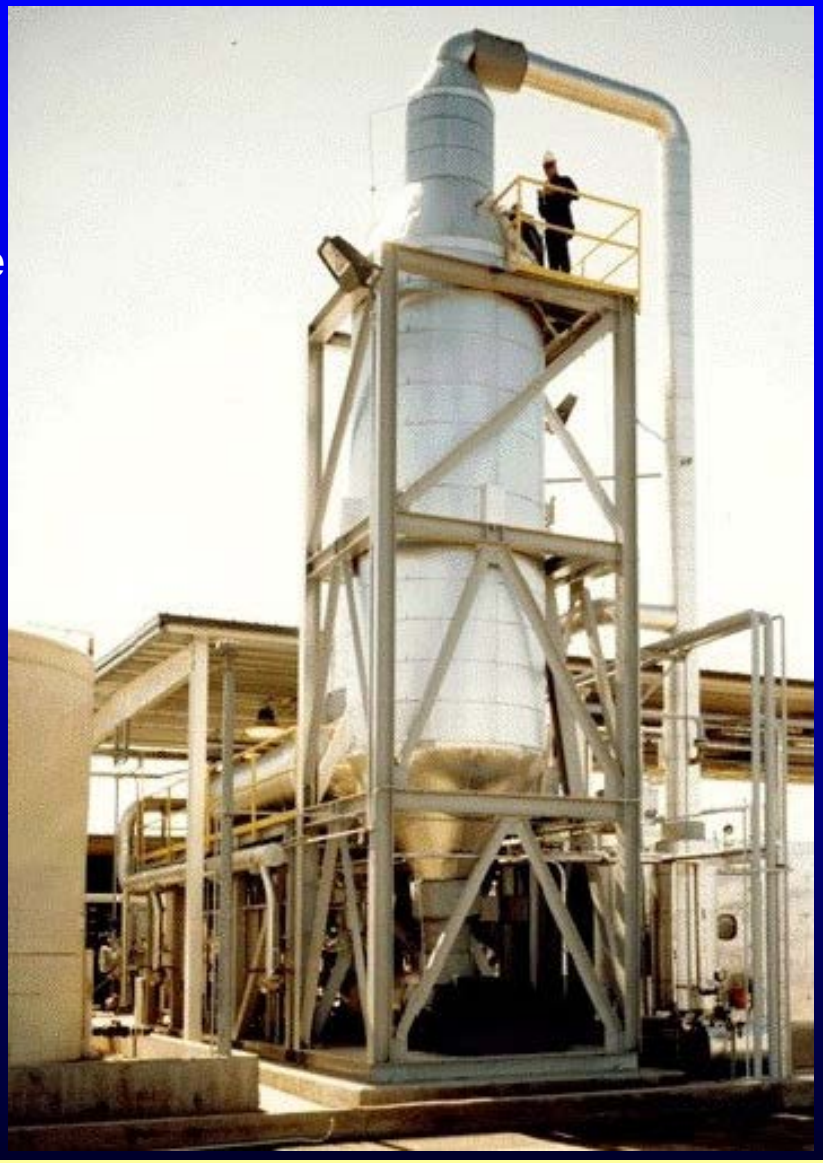
Zero Liquid Discharge

20 to 400 gpm

685 to 13570 bpd

Inlet 300,000 mg/l

Outlet Water/Salts

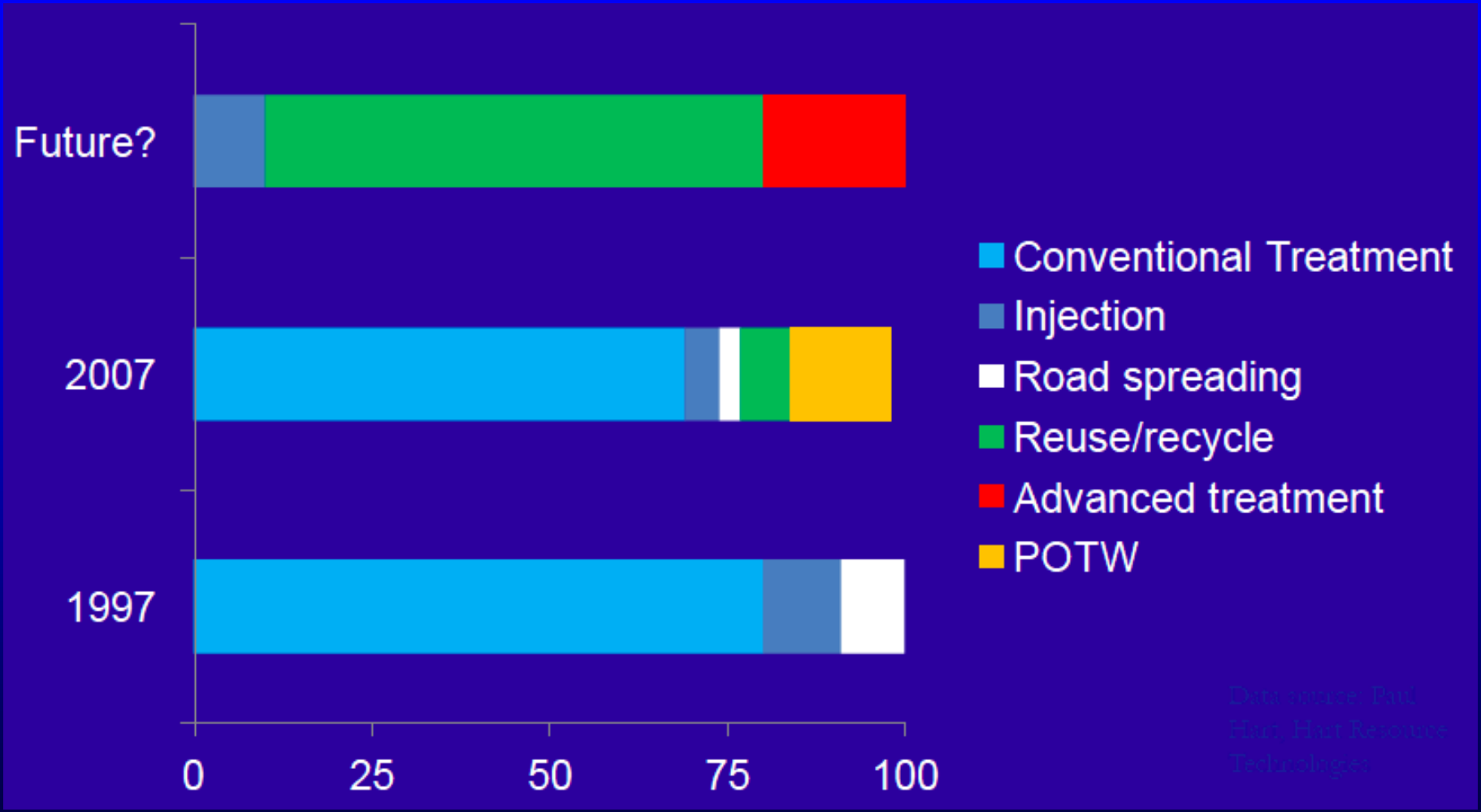


Salt production

- 100,000 wells
- 10 barrels/day/well of produced water
- 300,000 mg/L salinity of produced water
- 80% salt recovery

- Total NaCl produced in PA = 8 million tons
- Total salt use for deicing in the US = 12-15 million tons

Gas Drilling Wastewater Management



(Hart, P., 2011)

Summary and Conclusions

- Water supply is not a major issues in water-rich PA; may be a concern for 3rd and 4th order streams
- No viable disposal options for gas drilling wastewater in PA and very few treatment options for disposal
- Flowback water reuse appears to be the most effective option
- Water reuse has a finite shelf life
- Need to develop technologies that would enable final disposal of wastewater
- Salt management will become a major issue in PA

Thank You for Your Attention

Questions?